Survey of Moel Farlwyd

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1) Introduction

Moel Farlwyd (Hill Number 3366, Section 30D, OS 1:50000 Map 115, OS 1:25000 Map OL18E, Grid Ref. SH707486) is listed as a sub Hump (a hill with greater or equal to 90m but less than 100m of drop) in the Database of British and Irish Hills (DoBIH); in this case with 98m of drop. As the drop has been calculated from the OS map contours, there is possibility that it could exceed 100m and therefore Moel Farlwyd would be reclassified as a Hump.

The purpose of this survey was to measure accurately the drop of Moel Farlwyd and thereby resolve its classification.

2) Equipment used and Conditions for Survey

A Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a "1m" **E**-staff extendable to 5m were used to determine the positions of the bwlch and summit.

Absolute heights were measured using a Leica Viva GS15 receiver. This receiver is a dual-frequency, multi-channel instrument, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receiving two signals (at different frequencies) from each of these satellites. The latter feature reduces inaccuracies that result from atmospheric degradation of the satellite signals. As a stand-alone instrument, it is capable of giving position and height to an accuracy of about two metres and five metres respectively.

Note that small hand-held GPS receivers used for general navigation can only receive up to 12 GPS satellites and each at a single frequency and therefore these instruments have a poorer positional accuracy of +/-5 metres and a height accuracy of no better than +/-10 metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improve the speed at which these units can achieve a satellite "fix".

Despite the on-board features of the Leica Viva GS15 receiver, there are still sources that create residual errors. To obtain accurate positions and heights, corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey, which were post-processed using Leica GeoOffice 8.3. Repeated 1hr measurements with the Leica Viva GS15 on the same position give a height precision of +/-0.06m (to three standard deviations).

Conditions for the survey, which took place between 11.30hr and 15.30hr GMT, were good. The weather was cool, 5 degrees Celsius, with very light wind and sunshine. Visibility was excellent.

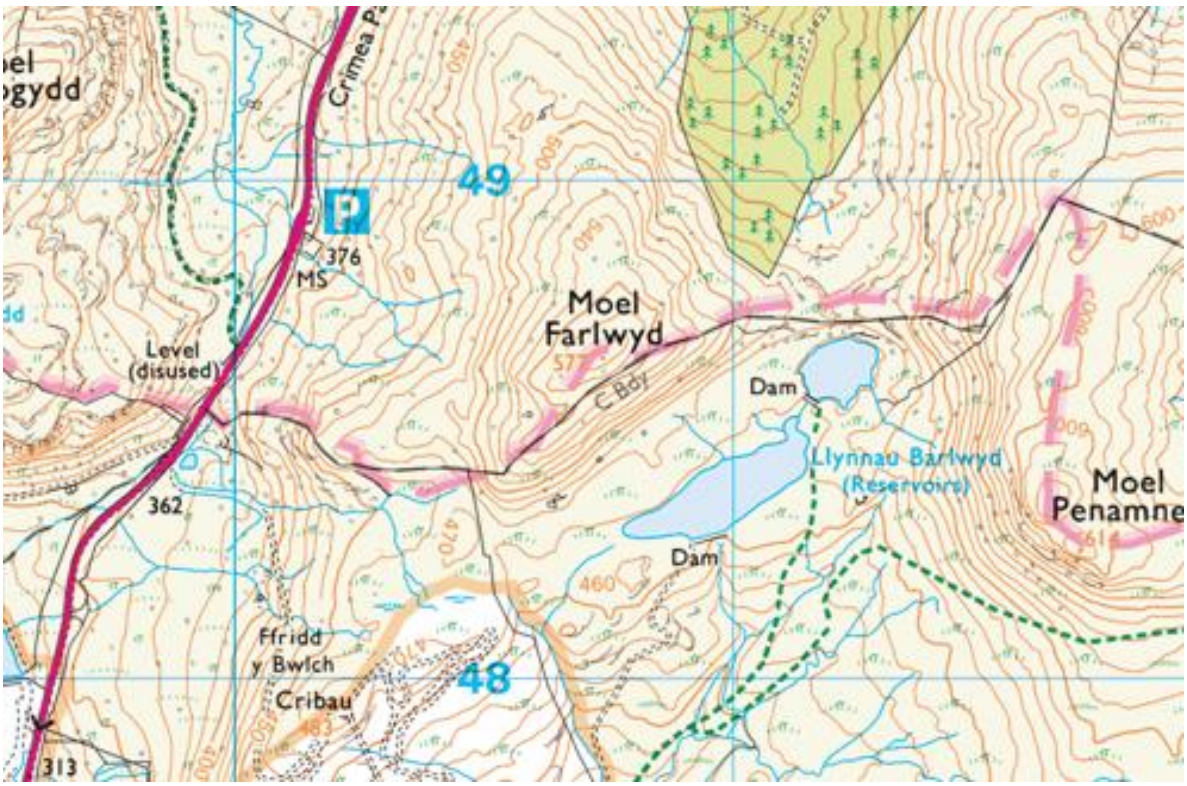
3) The Survey

3.1) Character of Hill

Moel Farlwyd lies in the south east of Snowdonia about 4km north of the slate mine town of Blaenau Ffestiniog. It is part of a chain of hills and mountains that runs south from Carnedd y Cribau, 7km east of Snowdon, to Blaenau Ffestiniog where it turns east over the Crimea Pass on the A470 to Moel Farlwyd and on to Moel Penamnen and Foel-fras. The whole area is dominated by

the slate quarries, mostly now disused, that in former times were said to “roof the world” This area is very important historically because of this industry and a recent application has been made for it to become a “World Heritage Site”.

An extract of the Ordnance Survey 1:25000 scale map (Crown Copyright Ordnance Survey) showing the summit and col situated about 500m ENE of the summit, is presented below. The summit is marked with a spot height of 577m and the contours around it are elliptical showing a ridge in a SW to NE direction. The descent to the col, no spot height, is quite steep and the col lies north of the Llynnau Barlwyd (reservoirs).



Moel Farlwyd is typical of the Moelwyns, the group of hills to which it belongs. These hills are grassy with rocky outcrops and crags culminating in distinct summits. Moel Farlwyd is no exception, although its west flank is mostly composed of tussock grass and there is little rock compared with its eastern flank. The summit is distinct and marked with a small cairn next to a vegetated rocky rib.

The easiest access to Moel Farlwyd, which we used, is from the lay-by/car park on the A470 near the top of the Crimea Pass, a distance of less than 1km from the summit. As the hill is 577m high and the starting point is marked with a spot height of 376m, this route only requires 200m of climbing over fairly steep grass. Just to the west of the layby/car park there is a stile with a faint track leading away from it. However, this track is soon lost within sheep tracks and we found it quicker to plod up the grass rather than try to search out the route of the track.

3.2) Summit

The approximate position of the summit next to the cairn is easily identified with the unaided eye. However, the Leica NA730 automatic level was set up on a small grassy knoll several metres NE of the summit and staff readings were taken around the small cairn. The highest point was found to be on a vegetated rocky rib next to the cairn. The cairn was also partly dismantled (and replaced) to check that there was no higher ground underneath it. We also checked high points to the NE with staff readings, but these clearly showed the ground was descending in that direction.

The Leica GS15 was setup directly over the summit position using the "short tripod" assembly (see photographs in Appendix). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.421m plus 0.255m for the tribrach/hook system. GNSS data were collected for 1 hour with an epoch time of 15 seconds.

The data were processed in Leica GeoOffice 8.3 using the six nearest base stations under 100km distance from the survey point and the Hopfield Tropospheric model. The results are given in the table below: -

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
Leica Viva GS15	270738.188	0.002	348643.172	0.003	575.702	0.013

The height of Moel Farlwyd is 575.7m.

3.3) Col

On descending from the summit to the col, the ground appeared to be more complex than the map suggested and that there could be more than one col to survey. However, one col was clearly identifiable and distinct, but there appeared to be another col closer to Moel Penamnen with an intervening rise that obstructed its details. Therefore, our first task was to identify which was the critical col. Inspection of the col nearer Moel Penamnen showed higher ground to be concealed behind the intervening mound but only marginally lower than the intervening mound itself. We could estimate that this was approximately 3m higher than the other col and so did not need to be surveyed.

Having returned to the first col, its position was easily identified visually. In the hill to hill direction, the line of the col rose quite steeply towards Moel Penamnen but more shallowly in the opposite direction. Also, at this point, there was a fence in the hill to hill direction that very closely appeared to follow the line of the col. Certainly to the south side of this fence the ground fell away noticeably, indicating that we needed to concentrate our surveying on the north side of the fence only.

In the col area we set up a matrix of flags, three rows in the valley to valley direction with five flags in each row. The flags and rows were set about 2.5m apart. The Leica NA730 level was then setup at a convenient point west of this matrix of flags and staff readings were taken at each flag position. These measurements showed that the position of the col had been identified correctly.

The Leica GS15 was setup directly over the col position using the "short tripod" assembly (see photographs in Appendix that also show the matrix of flags). The height of the receiver above the ground was then measured with the integral tape. The vertical offset from measuring point to the ground was 0.675m plus 0.255m for the tribrach/hook system. GNSS data were also collected for 1 hour with an epoch time of 15 seconds. The processing of the GNSS data was carried out as for the summit.

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
Leica Viva GS15	271144.182	0.002	348719.943	0.002	474.276	0.010

Therefore, the height of the col for Moel Farlwyd is 474.3m

4) Summary of Operating Conditions

	GS15
Data Collection bwlch (min)	65
Data collection summit (min)	65
Number of Base Stations used in Processing for all points	6
Epoch Time (sec)	15
Tropospheric Model	Hopfield
Cut off Angle (degs)	15
Geoid Model	OSGM15

5) Coordinate Recovery

In order to verify the precision and consistency of a GNSS dataset, Ordnance Survey (OS) recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under approximately100km distance, as used in this report, the data are first processed with reference to only the nearest Base Station, in this case St Asaph (ASAP). The data are then reprocessed with the survey point taken as a Reference Point and all the remaining Base stations taken as survey points. These measured values for the OS Base Stations can then be compared directly with the actual OS values for position and height. (This has been carried out via an Excel spreadsheet supplied to us by OS).

Although the spreadsheet calculates a number of different parameters, two important ones are presented in the tables below. “Height Difference U metres” is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. “Separation D_{ij} metres” is the distance in 3-d space between the measured and actual OS values for each Base Station. The results for the summit and col measurements for Moel Farlwyd calculated using the Hopfield tropospheric model are presented below.

			Summit	Summit	Col	Col
Base Station	Code	Distance to Survey Point km.	Height Diff. U metres	Separation D_{ij} metres	Height Diff. U metres	Separation D_{ij} metres
St Asaph	ASAP	41	Reference	Reference	Reference	Reference
Machynlleth	MACY	48	-0.0033	0.0060	0.0072	0.0075
Holyhead	HOLY	58	0.0194	0.0246	-0.0202	0.0225
Aberdaron	ABER	59	-0.0452	0.0463	-0.0122	0.0147
Shrewsbury	SHRE	89	-0.0560	0.1096	0.0282	0.0293
Daresbury	DARE	94	0.0481	0.0497	0.0466	0.0488
Crewe	CREW	104	0.0308	0.0318	0.0377	0.0381
Blackpool	BLAP	104	0.0348	0.0357	0.0265	0.0266
Aberporth	ABEP	106	-0.0293	0.0297	0.0120	0.0144
Shobdon	SHOD	111	-0.0135	0.0160	0.0187	0.0187

Apart from Shrewsbury (SHRE) for the calculation from the summit, the results show consistent datasets, as all measured OS Base Stations are within 0.05m distance and height of the OS actual values for Base Station distances up to about 111km. and are below the 0.1m requirement of OS. Normally coordinate recovery is only considered up to 100km distance but there are only six Base stations in this part of Wales that can satisfy that requirement. Therefore, for this survey we extended the distance to 111km to increase the number of Base Stations used to ten with no apparent loss in accuracy.

The summit result for SHRE is 0.11m for distance and height of the OS value and therefore beyond the 0.1m requirement. However, the height difference is only 0.06m, showing that the anomaly in this one piece of data is with the calculation of the Base station's position rather than its height.

6) Discussion of Results

For the GNSS results from the Leica Viva GS15, a 1-hour data collection time gives results with a measurement uncertainty of +/-0.06m. This measurement uncertainty applies to both the col and summit measurements. The measurement uncertainty in height associated with the location of the summit is estimated to be +/-0.005m as this position was on rock and could be accurately determined. However, the measurement uncertainty in height associated with the location of the col is much greater because of the tussock grass and vegetation in this area. We estimate this uncertainty to be +/-0.05m.

Combining the uncertainties estimated above we give the overall values as: -

Summit – [square root ($0.06^2 + 0.005^2$] = +/-0.06m.

Col - [square root ($0.06^2 + 0.05^2$)] = +/- 0.08m.

Drop - [square root ($0.06^2 + 0.005^2 + 0.06^2 + 0.05^2$)] = +/-0.1m.

The drop for Moel Farlwyd calculates to be 575.7m – 474.3m = 101.4m. This is 1.4m more than the minimum requirement of 100m for this hill to be classified as a Hump. Since this difference is much

greater than the total uncertainty in the drop measurement, we can confirm the reclassification of Moel Farlwyd.

7) Summary and Conclusions

The **summit** of **Moel Farlwyd** is at grid reference * SH 70738 48643 and is a vegetated rock rib next to a cairn. Its height is **575.7m+/-0.06m.**

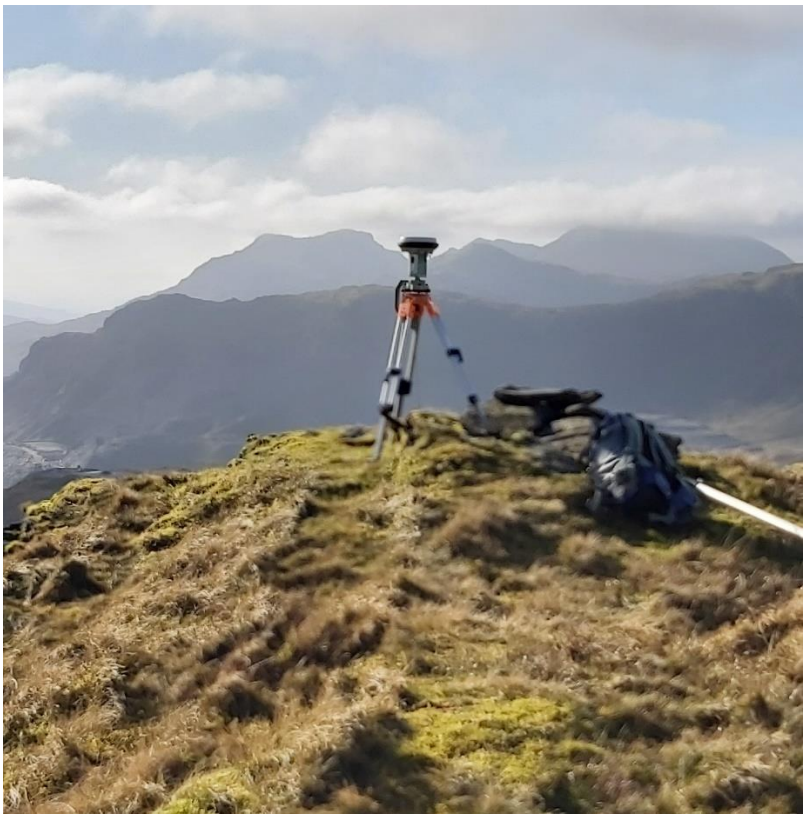
The **col** of **Moel Farlwyd** is at * SH 71144 48719 and is unfeatured ground. Its height is **474.3+/-0.08m**.

The **drop** for **Moel Farlwyd** is **101.4+/-0.1m** and consequently this hill is reclassified as a **Hump.**

- NB: Grid references for OSTN15 are quoted in the summary.

John Barnard and Graham Jackson, 09 February 2020

Appendix 1



Leica GS15 collecting data on the summit of Moel Farlwyd.

Offset for GS15 on summit.

Leica GS15 set-up at col, looking towards Moel Penamnen

Offset for Leica Viva GS15 set-up at col